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RECENT DISCOVERIES CONCERNING THE LIFE HISTORY OF *ASCARIS LUMBRICOIDES* *

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Ascaris lumbricoides is one of the most common and most important intestinal parasites of man. A roundworm sometimes known as *Ascaris suum,* or *A. suilla,* but morphologically indistinguishable from *A. lumbricoides* and probably of the same species, is of very frequent occurrence in the intestine of the pig. Until recently it had been generally assumed by parasitologists upon the basis of evidence collected by various investigators that the life cycle of *Ascaris lumbricoides* is simple and direct, that the eggs of the parasite which pass out of the intestine of the host animal in the feces, are swallowed by another human being or pig after a period of incubation sufficient for the development of the contained embryos to a vermiform stage, and that having been swallowed the eggs hatch in the alimentary tract, after which the embryos develop to maturity in the small intestine, the normal location of the adult worms. Stewart, however, in a series of notable papers (1916-1918) has lately presented the results of some investigations which have revealed imperfections in our former ideas of the life history of *Ascaris lumbricoides.* His contributions to our knowledge of this common parasite afford another striking illustration of the fact that prevailing and apparently well established views as to the life histories of parasites are often wrong.

Stewart first attempted to infect pigs by feeding them Ascaris eggs but failed. He then fed the eggs to rats and mice, and discovered that they hatched out in the alimentary tract, a fact already established by Davaine (1863), who also noted that newly hatched larvae could be found in the feces of rats soon after feeding the eggs. Stewart observed further, however, that not all of the young worms are thus eliminated in the feces. On the contrary many of them penetrate the

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intestinal wall and, aided by the circulation, migrate to the liver, spleen and lungs, and may be found in the liver and lungs two to four days after infection. He determined that the migrating worms undergo considerable growth and development, and in fact increase in length from about 0.22 mm. to as much as 1.4 mm. within a week after infection. They can be found in the bronchi and trachea seven or eight days after infection, later in the mouth, then in the esophagus, stomach and intestine. Having reached the intestine after their migrations through the lungs the larvae linger for a time in the cecum, but ultimately pass out of the body in the feces without development beyond the stage already reached in the lungs, except that they may become slightly larger reaching a maximum length of nearly 2.5 mm. According to Stewart, a rat or mouse may become quite free of the parasites as early as 16 days after infection. During the invasion of the lungs by the worms Stewart found that rats and mice commonly died from pneumonia. Influenced by his failure to infect pigs through feeding them Ascaris eggs and by his discovery of the behavior of the larval parasites in rats and mice, Stewart concluded that these animals act as intermediate hosts, the young worms being passed on to human beings and pigs through the contamination of food, water, etc., by the saliva or feces of rats or mice that had themselves become infected by swallowing the eggs of the parasite. It is necessary to admit that infection of man or pig in this way is theoretically possible, but it appeared to the writers following the publication of Stewart's earlier papers, that this explanation of the mode of infection was inadequate.

We had for a number of years been carrying on certain investigations relating to Ascaris in which infested pigs were utilized, and had repeatedly attempted to secure heavily infested subjects by feeding the animals with Ascaris eggs, but with very unsatisfactory results, so that our early experience with pigs was very similar to Stewart's. Nevertheless the results of Stewart's experiments with rats and mice and his failures and our failures to infect pigs did not seem necessarily to lead to the conclusion that rats and mice normally serve as intermediate hosts of *Ascaris lumbricoides*. The questions raised by Stewart's investigations were highly important from a practical as well as a purely scientific standpoint, and it appeared desirable that the Bureau of Animal Industry should collect further data that might assist in reaching definite conclusions. Accordingly the present writers repeated and supplemented Stewart's experiments. Without going into all the details of our work at this time, it may be stated that we have confirmed Stewart's results as to the behavior of Ascaris larvae in rats and mice. We have, however, in addition, made obser-

vations that appear to us to demonstrate very clearly that rats and mice are not normal intermediate hosts as Stewart suggested. In our opinion the real explanation of the behavior of Ascaris larvae in rats and mice is that the worms are merely going through the same course as they do in their usual hosts, man and pig. The only essential difference in the two instances is that in unsuitable hosts such as rats and mice the parasites are unable to complete their development to maturity, whereas in human beings and pigs after their migration through the lungs and return to the alimentary tract they can continue their growth to the adult stage. The value of Stewart's investigations, therefore, lies in the establishment of certain important facts relating to the migration of Ascaris larvae and not in the suggestions that he has made with reference to rats and mice as intermediate hosts.

In guinea-pigs and rabbits we have found that the larvae behave as they do in rats and mice with respect to their development, migration and elimination, and the fact that they are liable to cause a more or less serious pneumonia. From a young goat and a lamb after feeding them eggs of the pig Ascaris we have recovered immature worms that had developed beyond any stage yet obtained from rats, mice, guinea-pigs, or rabbits. In the case of the lamb, which two days after birth was fed Ascaris eggs and killed 103 days after feeding, we found in the intestine fifty partially grown ascarids, twelve males and thirty-eight females, the smallest male 60 mm., the largest female 130 mm., in length. The minimum lengths of the adults are about 150 mm. (male) and 200 mm. (female). The goat four days after birth was given a dose of Ascaris eggs, and 17 days later, a second dose. Seven days after the second dose the animal began to show symptoms of pneumonia and died three days later. In the lungs, trachea, esophagus and stomach numerous Ascaris larvae were found ranging from 1 to 2 mm. in length. These undoubtedly are traceable to the second feeding with Ascaris eggs, 10 days previously. In the small intestine were thousands of young ascarids measuring about 10 mm. in length, and these are traceable to the first feeding with eggs that took place 27 days before the death of the animal. These worms had developed to about four times the length of the largest that have been observed in experiments with the smaller laboratory animals.

From these experiments it is clear that the parasites behave in sheep and goats just as they do in rats, mice, guinea-pigs and rabbits, with the exception that after their return to the alimentary tract they are able to continue their development and approach the adult stage. These experiments also lend support to the common belief among parasitologists that the so-called *Ascaris ovis* occasionally found in sheep is merely the pig Ascaris in a strange host. It is of interest to

note that the specimens of *Ascaris ovis* whose measurements have been recorded are smaller than full grown specimens of *Ascaris lumbricoides,* and that fertile eggs appear never to have been seen. These are circumstances that are in accord with the results of our experiments and support the view that the sheep Ascaris is a parasite in the wrong host. Evidently the Ascaris of the pig is better adapted to existence in the sheep and goat than in rats, mice, guinea-pigs and rabbits. Apparently, however, it is unable to adapt itself sufficiently to reach the full measure of development attained in its usual host, the pig. In a scale of host adaptations we may therefore recognize three grades, rats, mice, guinea-pigs and rabbits in the lowest; sheep and goats in the intermediate grade, and pigs in the highest, with which we may also include human beings, if it be true that the Ascaris of man and of the pig are identical.

In our experiments on pigs we have found that the ingestion of Ascaris eggs by these animals is followed by the same series of phenomena that was observed in the experiments on other animals, including in some instances the occurrence of pneumonia. This has been noted in a previous paper (Ransom and Foster, 1917), and Stewart in one of his later articles (1918) has recorded the results of some experiments in which he observed the migration of Ascaris larvae through the lungs of pigs and the occurrence of pneumonia in these animals. Stewart, however, expressed himself as still unwilling to admit the development of Ascaris without an intermediate host. Owing to certain practical difficulties the experiments that we have thus far carried on with pigs as subjects have not been sufficiently controlled to exclude the possibility of the pigs themselves acting as their own intermediate hosts. That is, in all the cases in which we obtained intestinal infection with mature or nearly mature Ascaris following the feeding of the eggs to pigs, it is possible that the worms found had been reingested by the pigs after they had been passed out in the feces, continuation of their development beyond the lung stage having occurred only after such elimination and reingestion. So far, therefore, as our experiments on pigs are concerned, we cannot point to definite results disproving Stewart's views as to the necessity for an intermediate host. On the other hand no good evidence has yet been brought forth that Ascaris larvae after their migration through the lungs of an animal must necessarily pass out of the body and be reingested by the final host before they can develop to maturity.

There are certain important facts which have already been mentioned or alluded to by Lane (1917) and Low (1918) that are quite out of harmony with the hypothesis of the regular occurrence of the elimination and reingestion of Ascaris larvae as a necessity in the life

cycle. For example, the larvae after their migration through the lungs and elimination in the saliva or feces have very little resistance to unfavorable conditions, and though in moist media they can be kept alive for a time they quickly succumb to drying, a condition to which they are particularly liable to be exposed. The feeble resistance of the larvae after their passage through the lungs may be contrasted with the remarkable vitality of the eggs which have been kept alive for as long as five years, resist long periods of dryness, and are not killed by considerable periods of exposure to temperatures far below freezing. The egg stage is thus well adapted to withstand the hardships which the parasite must endure in its passage from one host to another, whereas the larvae that have passed through the lungs are not at all adapted to such an existence. On general principles it hardly seems probable that Ascaris could continue to exist if infection of the final host were brought about only by the ingestion of larvae which had already passed through the body of another animal and had been left exposed to the vicissitudes of the outer world in a feebly resistant condition.

As already stated, however, it may be admitted that infection in this way possibly sometimes occurs, though it has not yet been proved. On the other hand, the results of our experiments with the young lamb and the kid supply very strong proof of the correctness of the view that the final host becomes infected by swallowing properly incubated eggs and not by swallowing larvae that have passed through an intermediate host. In these experiments the very nature of the animals as well as their age practically excludes the possibility of infection through reingestion of larvae that had passed out of their bodies and dropped to the ground. In the light of the evidence from these experiments as well as that from the experiments with rats, mice, guinea-pigs, rabbits and pigs, and taking into consideration also the evidence which has been gathered by various investigators with reference to Ascaris infection of human beings, no other reasonable conclusion can be reached than that Ascaris has a direct life history without intermediate host, that infection occurs as a result of ingestion of the eggs, and that the larvae after migrating through the lungs return to the alimentary tract, settle down in the intestine if the animal is a suitable host and develop to maturity. It may be mentioned that very young pigs appear to be not only more susceptible to infection with Ascaris, but also more liable to develop pneumonia than other animals.

With reference to the production of pneumonia by Ascaris larvae it is of interest that Mosler (according to Leuckart, 1867) and Lutz (1888) observed lung symptoms in human beings a few days after the

ingestion of Ascaris eggs. In addition to the likelihood that Ascaris infection will be found to be responsible for certain lung troubles in human beings, particularly in children, it is quite likely that Ascaris has something to do with many of the cases of lung disease in pigs. Large numbers of young pigs suffer and die from lung affections the causes of which have never been satisfactorily explained. The symptoms shown by experimentally infected pigs at the time of the invasion of the lungs by the larvae are frequently exactly similar to those exhibited by pigs suffering from so-called "thumps," a popular name for a serious condition of very common occurrence among pigs, and it is accordingly not improbable that Ascaris is an important factor in the production of "thumps," especially when it is considered how very commonly Ascaris occurs as a parasite of pigs. Though we can not yet form a true estimate of the actual importance of Ascaris as a cause of lung disease it is evident that this parasite has capacities for harm not formerly suspected. Stewart's very interesting discovery of the migration of the larvae through the lungs has therefore not only added materially to our knowledge of the life history of Ascaris, but also by opening up a new line of investigation in pathology is likely to lead to a better understanding of the cause, prevention and treatment of certain diseases of the lungs.

The hatching of the eggs of Ascaris is an interesting question. It has been found by different investigators that when the eggs are swallowed hatching occurs in the small intestine. Hatching results not from any apparent digestion of the egg shell but from the active penetration of the shell by the contained embryo. Some writers have found that hatching will occur outside the body if the eggs are placed in certain solutions. We have been unable, however, to cause more than a very small percentage of the eggs to hatch outside the body in vitro. The factors which bring about the hatching of the eggs have not yet been determined. It is a noteworthy fact that if the eggs are injected beneath the skin of a guinea-pig they not only hatch, but that the larvae later appear in the lungs as they do following infection by way of the mouth, reaching a length of 0.5 mm. in seven days, and of 1.5 mm. in eleven days after the eggs are injected. Martin (1913) observed that the eggs of *Ascaris vitulorum* would hatch when introduced beneath the skin of a guinea-pig, but he did not follow the migrations of the larvae.

References Cited

Davaine, C. J. 1863.—Nouvelles recherches sur le développement et la propagation de l'ascaride lombricoide et du trichocéphale de l'home. Compt. rend. Soc. biol., Paris, (3) 4: 261-265.

Lane, Clayton. 1917.—*Ascaris lumbricoides* and coprophagia. Indian Med. Gaz., 52: 269-272.

1917.—Major Stewart on *Ascaris* infection. Indian Med. Gaz., 52: 301.

1917.—The life history of *Ascaris lumbricoides*. Indian Med. Gaz., 52: 380.

Leuckart, Rudolph. 1867.—Die menschlichen Parasiten und die von ihnen herrührenden Krankheiten. v. 2, 1. Lief.

Low, G. C. 1918.—The life-history of *Ascaris lumbricoides*. Brit. Med Jour., 1: 286.

Lutz, Adolph. 1888.—Zur Frage der Uebertragung des menschlichen Spulwurms. Weitere Mittheilungen. Centralbl. Bakter., 3: 425-428.

Martin, André. 1913.—Recherches sur les conditions du développement embryonnaire des nématodes parasites. Ann. sci. nat., zool., 18: 1-151.

Ransom, B. H., and Foster, W. D. 1917.—Life history of *Ascaris lumbricoides* and related forms. Jour. Agric. Research, 11: 395-398.

Stewart, F. H. 1916.—On the life history of *Ascaris lumbricoides*. Brit. Med. Jour., 2: 5-7.

1916.—The life-history of *Ascaris lumbricoides*. Brit. Med. Jour., 2: 474.

1916.—Further experiments on Ascaris infection. Brit. Med. Jour., 2: 486-488.

1916.—On the life-history of *Ascaris lumbricoides*. Brit. Med. Jour., 2: 753-754.

1917.—On the development of *Ascaris lumbricoides* Lin. and *Ascaris suilla* Duj. in the rat and mouse. Parasitology, 9: 213-227.

1917.—Note on *Ascaris* infection in man, the pig, rat, and mouse. Indian Med. Gaz., 52: 272-273.

1917.—The life-history of *Ascaris lumbricoides*. Indian Med. Gaz., 52: 379-380.

1918.—On the development of *Ascaris lumbricoides* and *A. mystax* in the mouse. Part 2. Parasitology, 10: 189-196.

1918.—On the life history of *Ascaris lumbricoides* L. Parasitology, 10: 197-205.